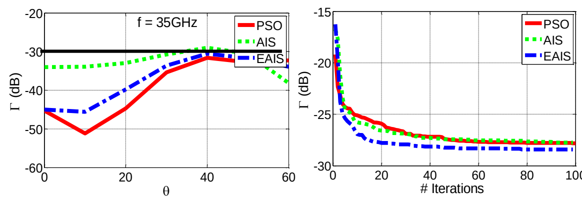


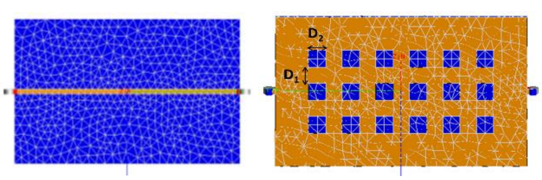
(a) (b)

Fig. 7. Optimized AR surface design at f = 35 GHz and performance of three algorithms.

B. Microstrip EBG structures

In this application, we design a low pass filter operating at [4-7.5 GHz] such that $S_{21} \geq -5$ dB across [4-6 GHz], and $S_{21} \leq -25$ dB over [6.5-7.5 GHz]. To achieve the performance, we consider a 50 Ohm microstrip line symmetrically residing on a periodically etched ground plane, where 50 mil thick, 2.33x1.53 inches RT/Duroid 6010 ($\varepsilon_r = 10.2$) is used as the substrate. To model the structure, we use EM commercial software, FEKO, which is based on the Method of Moments (MoM).

The simulated model for our design is shown in Fig. 8. The optimization variables; i.e., D_1 and D_2 are set to be between 50-250 mils. The optimization parameters used for each algorithm are summarized in Table 3. The solution achieved by each algorithm is summarized in Table 4, and the achieved performance is plotted in Fig. 9. We observe that, all three algorithms converge to similar solutions. A plot of the best cost versus the number of iterations is shown Fig. 9 (b). Although EAIS reaches the vicinity of the desired solution fastest, PSO achieves the best cost in the end.



(a) Top view (b) Bottom view

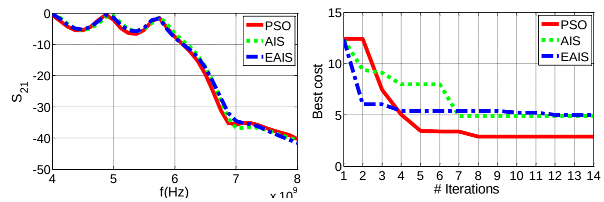
Fig. 8. Microstrip EBG line with etched squares in the ground plane.

Table 3: Algorithm parameters for microstrip EBG

	PSO	AIS	EAIS
N_a	10	4	2
N_b	n/a	12	12
# Cost computations/iteration	10	10	10
N_{max}	14	14	14

Table 4: Microstrip EBG design solution

	PSO	AIS	EAIS
D_1 (mil)	50	55	58
D_2 (mil)	222	216	213



(a) (b)

Fig. 9. Optimized microstrip EBG structure and performance of three algorithms.

IV. CONCLUSION

The robustness of the EAIS algorithm was demonstrated in comparison to PSO and AIS as they were applied to two electromagnetics applications; antireflective surface design using RCW, and microstrip electromagnetic band gap structure using MoM. EAIS consistently performed more robust than the other two algorithms. While it can never be claimed that a particular random search algorithm will always perform better than others, as the nature of a problem might fit the principles of an algorithm better at times, EAIS was shown to be consistently robust presenting itself as a viable tool for challenging electromagnetics problems.

REFERENCES

[1] R. L. Haupt, "An introduction to genetic algorithms for electromagnetics," *IEEE Antennas Propagat. Mag.*, vol. 37, pp.7-15, 1995.

[2] J. Kennedy and R. Eberhart, "Particle swarm optimization," *Proc. IEEE Int. Conf. Neural Networks*, vol. 4, pp. 1942-1948, 1995.

[3] L. N. De Castro and F. J. Von Zuben, "Learning and optimization using the clonal selection principle," *IEEE Trans. Evol. Comput.*, vol. 6, pp. 239-251, 2002.

[4] M. D. Gregory and D. H. Werner, "Design of high performance compact linear ultra-wideband arrays with the CMA evolutionary strategy," *IEEE Int'l Symp. on Ant. and Propag.*, Toronto, ON, 2010.

[5] R. S. Parpinelli, H. S. Lopes, and A. A. Freitas, "Data mining with an ant colony optimization algorithm," *IEEE Trans. Evol. Comp.*, vol. 6, iss. 4, pp. 321-332.

[6] O. Kilic and Q. Nguyen, "Application of artificial immune system algorithm to electromagnetics problems," *PIER B*, vol. 20, pp. 1-17, 2010.

[7] S. A. P. Ramaswamy, G. K. Venayagamoorthy, and S. N. Balakrishnan, "Optimal control of class of non-linear plants using artificial immune systems: application of the clonal selection algorithm," *22nd IEEE Int'l Symp. on Intelligent Control*, pp. 249-254, 1-3 Oct. 2007.

[8] M. S. Mirotznik, B. L. Good, P. Ransom, D. Wikner, and J. N. Mait, "Broadband antireflective properties of inverse Motheye surfaces," *IEEE Trans. Antennas Propagat.*, AP-58, 9, pp. 2969-2980, Sep. 2010.